Technology Opportunity

Integrated Controls and Control Synthesis Techniques

The National Aeronautics and Space Administration (NASA) seeks to transfer to industry advanced control design technologies that lead to enhanced performance in complex systems consisting of multiple interacting subsystems.

Potential Commercial Uses

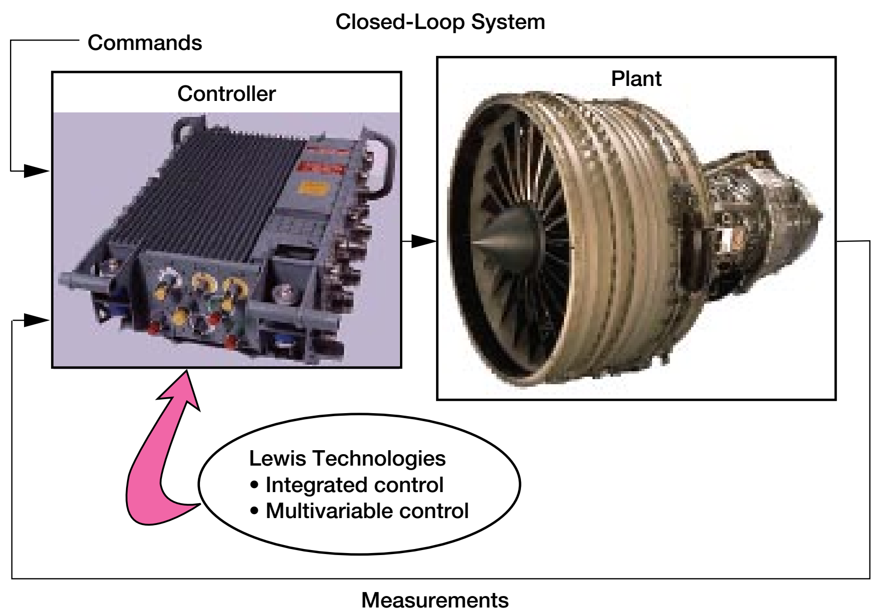
- Aerospace control applications (e.g., flight control and propulsion control)
- Automotive control applications (e.g., active suspension, engine control, and emissions control)
- Industrial process control (e.g., chemical plants)
- Control of manufacturing plants (e.g., paper industry)

Benefits

- Optimum system performance
- Reduced cost and time for control design and development
- New modes of operation for enhanced safety and performance

The Technology

The integrated approach developed at NASA Lewis is a systematic top-down method to design control laws for systems that consist of multiple interacting subsystems. In the classical approach to integrated control, separate (decentralized) control laws are designed for each subsystem and then integrated in an ad hoc manner to account for the interactions between the subsystems. This decentralized approach results in suboptimal system performance, which may lead to extensive redesign of subsystem control laws if the overall system performance is unacceptable. In the NASA-developed approach, a centralized control law that considers all the subsystem interactions is designed first; then these control laws are partitioned for decentralized implementation. The centralized design provides a baseline for



optimal achievable system performance, and controller partitioning yields implementable decentralized controllers that best match the optimal system performance for a given decentralized control architecture.

NASA Lewis has developed a procedure for integrated control design, with well-defined design steps and the technologies to implement each step. These technologies include the multivariable control synthesis approach, the integrator windup protection technique, and an optimization technique based on the newly developed concept of "evolutionary algorithms," which are further described in the following paragraphs.

In multivariable control design, the requirements are to meet desired performance, provide robustness to modeling uncertainties, and stay within control actuation limits while designing control systems that can be implemented within the limitations of available hardware. NASA Lewis has developed a procedure based on a modern control design technique called H-Infinity, which allows the designer to formulate the control synthesis problem to meet these requirements. This procedure has been successfully used by NASA Lewis researchers to design complex, multivariable flight and propulsion control systems.

Control systems that are designed for steady-state tracking of commands have integrators built into them. Logic has to be designed to prevent windup of these integrators when the steady-state errors cannot be forced to zero because of system limitations, such as actuator limits or safety limits. The design of integrator windup (IWP) logic is based on ad hoc techniques and a lot of experience—very few systematic approaches are available. The problem is especially complicated for designs of multivariable controls. Most existing approaches do not guarantee that the closed-loop system will be stable when the IWP becomes operative. NASA Lewis has developed a systematic procedure for the design of IWP gains; it guarantees closed-loop stability for saturation of a single actuator at a time, and allows for graceful degradation of performance as actuator limits are encountered. This approach can be implemented with commercially available control design software and has been successfully demonstrated on complex flight and propulsion control problems.

In the control design process, controller parameters often must be optimized to meet the system performance requirements. Evolutionary algorithms (EA's) based on the mechanics of natural genetics are an emerging technology for parameter optimization. Some advantages EA's offer over conventional optimization techniques are convergence to a global optimum, faster convergence, and application over a large class of problems. The University of Alabama, under a grant from NASA Lewis, has developed user-friendly software with a graphical user interface for applying EA's to control optimization problems. This software is based on commercially available control design software and implements newly developed algorithms that allow a faster solution to large problems.

Options for Commercialization

The technologies described herein consist mainly of concepts that have application to a broad class of products. Products in which robust multivariable control will provide significant improvement over traditional single-input single-output control can benefit most from these technologies. The technologies have been transferred to various aerospace industries through collaborative research. Some of the companies are further developing these technologies for specific application to their products. NASA Lewis is currently sponsoring a program with a major aircraft engine manufacturer to develop and evaluate advanced engine control laws by using these technologies. This program will help quantify benefits of the NASA-developed technologies and encourage industry usage through increased familiarization with and confidence in the technologies. If your company is interested in investigating the applicability of these integrated control and control synthesis techniques to your products, please contact us.

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